

Vegetation mapping of Svalbard, Arctic Norway, utilizing Landsat TM/ETM+ data

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 - Build and maintain research and development skills and quality at international level
 - Perform technology transfer and education at both pre- and post doc. level
 - Contribute to national innovation by establishing patents and new companies
- **The technological focus is on:**
 - Earth Observations and Remote Sensing
 - Information, and Communication Technology

Svalbard – Arctic Norway

- At present Arctic areas are highly focused due to the ongoing global climate change discussions.
- The area includes a transition from Middle Arctic Tundra Zone (MATZ) in the south to Arctic Polar Desert Zone in the north, with the Northern Arctic Tundra Zone in an intermediate position (Elvebakk 1997, 1999)
- The criteria's of defining the major bioclimatic zones within the Arctic have been agreed upon among northern scientists (CAVM_Team 2003; Walker et al. 2005)
- However, the efforts of delimitation zones and sections for Arctic areas are still an ongoing process, especially at local and regional levels
- In this process vegetation maps at various scales are needed

Arctic – Bio-geographic Zones

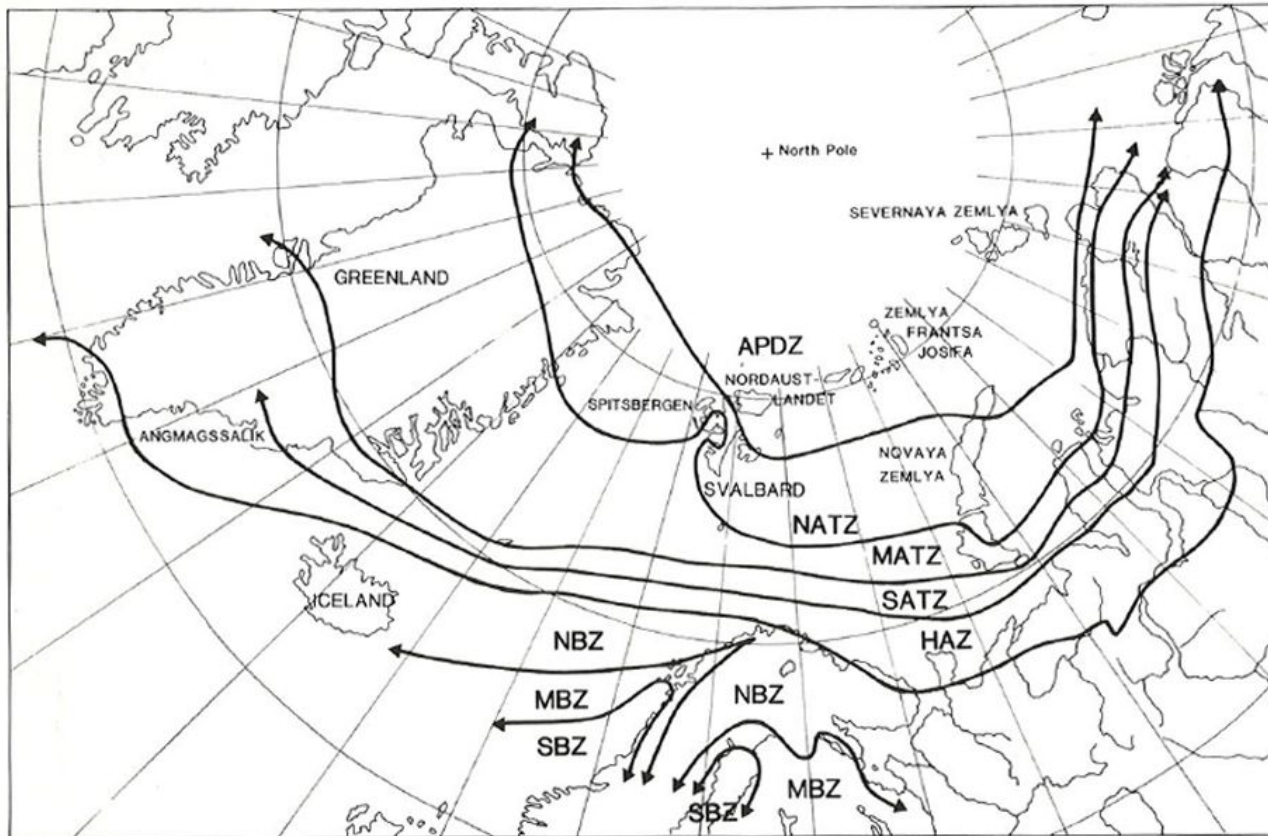
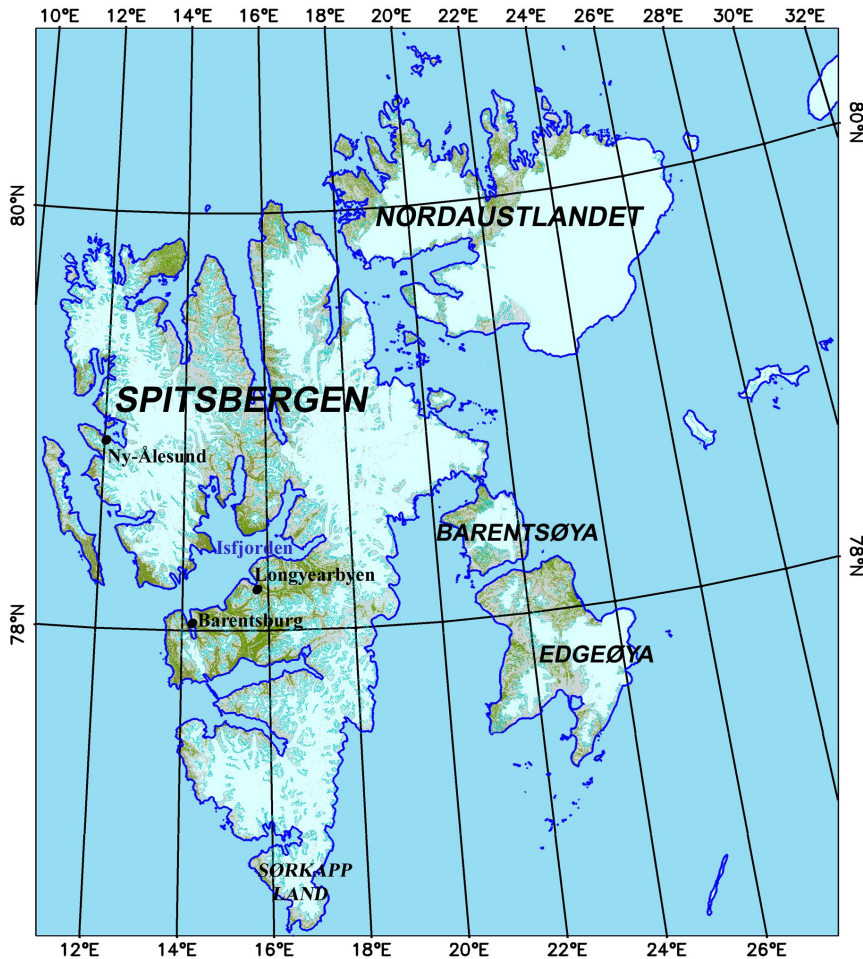


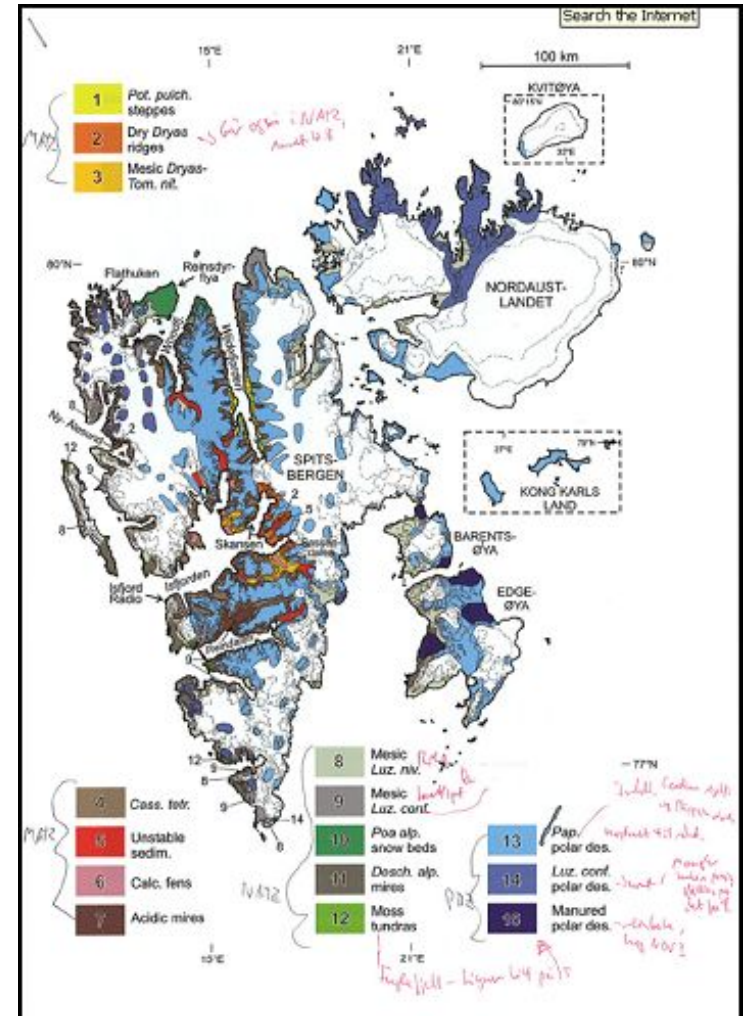
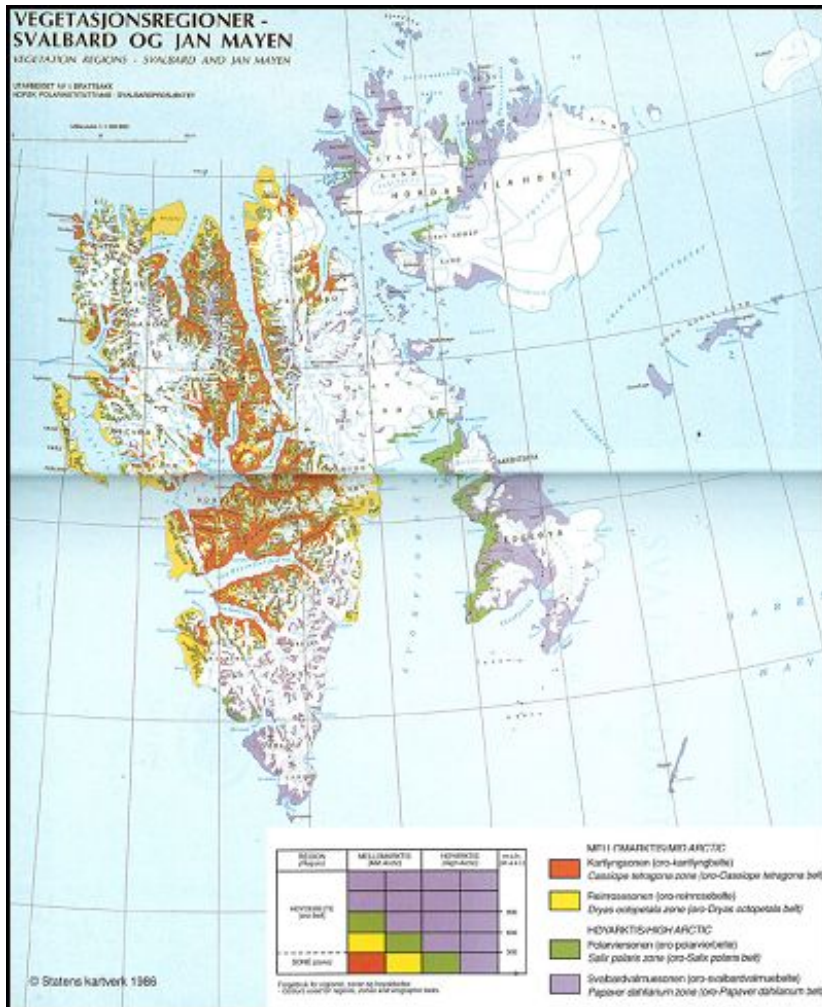
Fig. 3. Subdivision of the European Arctic and adjacent areas. APDZ = Arctic polar desert zone. NATZ = Northern arctic tundra zone. MATZ = Middle arctic tundra zone. SATZ = Southern arctic tundra zone. HAZ = Hemiarctic zone. NBZ = Northern boreal zone. MBZ = Middle boreal zone. SBZ = Southern boreal zone. The borders drawn at sea do not represent a classification of marine areas.

Svalbard mapping – local scales



- Base line registrations varies
- Areas in the west highly recorded (Brøgger Peninsula, Kapp Linné, Isfjord, Reindalen, Hornsund, Edgeøya)
- Other areas – not visited by any botanists (north and northeast)
- Coarse-scaled vegetation map (Elvebakk 2005)

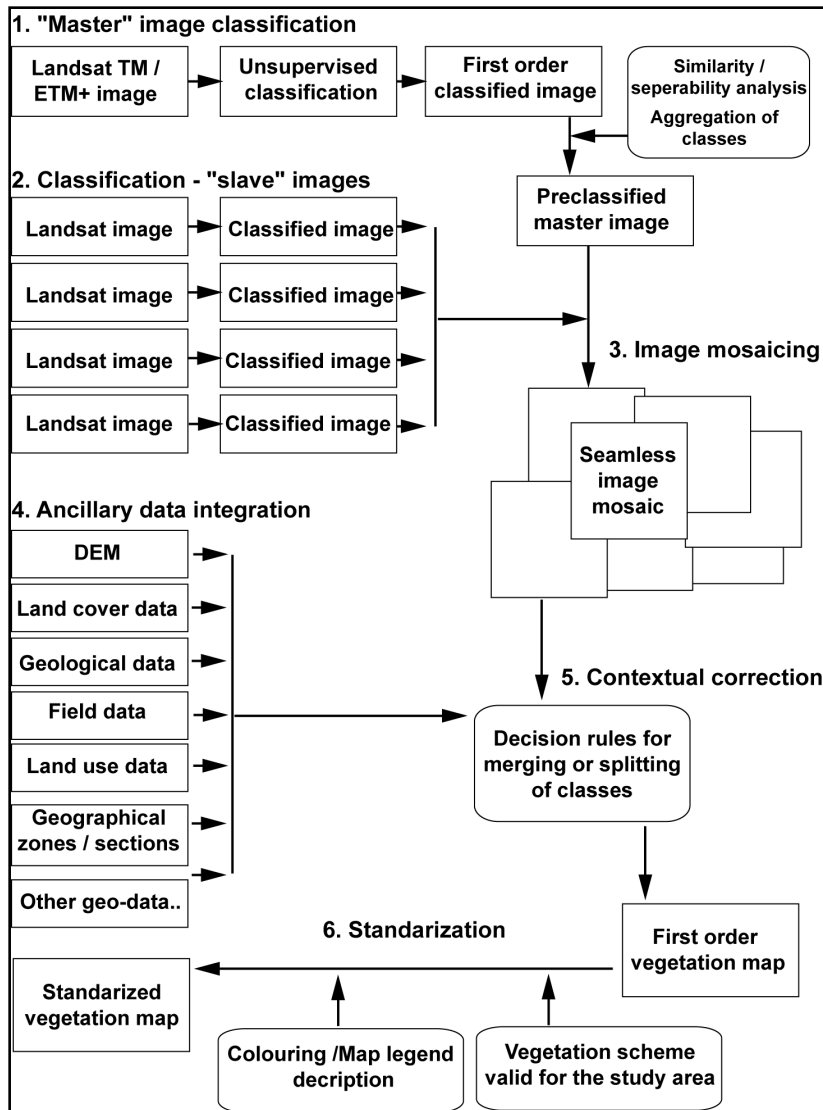
Vegetation maps - Svalbard



Objectives of this work

- The overall aim of the performed mapping has been to generate a generalized, consistent, and seamless vegetation map for the study area
- Develop methods for creating large-area vegetation maps based on Landsat TM/ETM+ images
- Create a reasonably accurate land-cover data set appropriate for a wide variety of end-users
- Figure out some improvements to the map by combining different satellite data resources

Classification scheme



Operational stages:

- Pre-classification (1-3): Image classification, spectral analysis, separability analysis, description of spectral classes, image mosaic
- Post-classification (4,5): Integration of ancillary data (DEM, land cover data, field inventory data)
- Standardization (6). Relate the map units to a classification system valid for the area

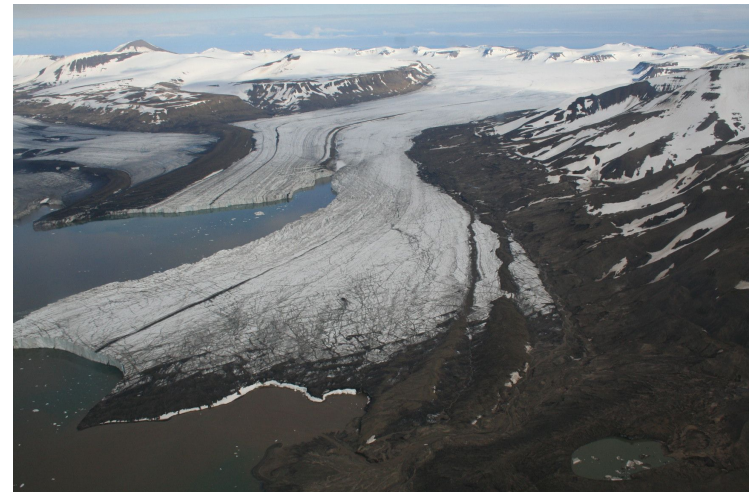
The map product

- Based on 11 Landsat TM/ETM+ images
- 18 map units aggregated from 37 spectral classes
- Master image acquired 17th of August 2000
- Classification of the master image – 32 classes
- 5 new classes added during the classification of additional images



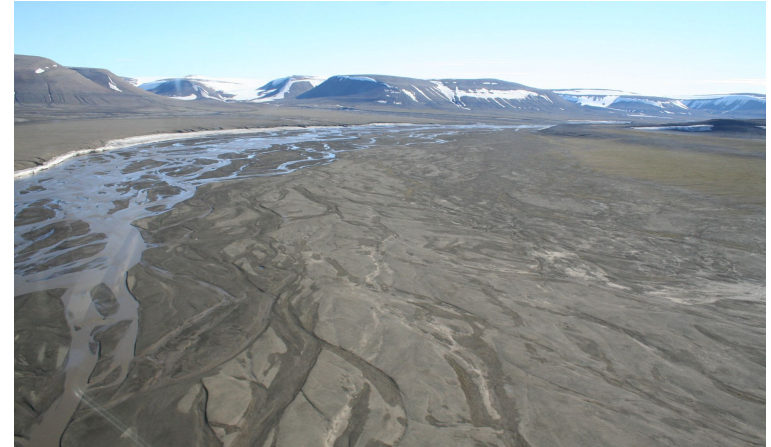
Map legend descriptions

- 1 - **Sea, oceans (1).** Bordering oceans to the archipelago are the Barents Sea in east, the Polar Sea in north and the North Atlantic in south and west.
- 2 - **Inland water (2)** Inland water is generally sparsely represented on Svalbard. The largest lakes and inland waters are found in the north, often bounding the glaciers.
- 3 - **Broad flooding rivers (3).** The extent of rivers varies highly during the summer period from large flooding rivers in the melting period to smaller extent in the late summer and autumn period.
- 4 - **Glaciers (4,6,32).** The glaciers constitute the prevailing landscape on Svalbard. The appearance of the glaciers varies highly from smaller valley and cirque glaciers, to large, continuous inland glaciers. On the eastern islands, large ice caps are common. To some extent late snow patches are aggregated in this map unit.

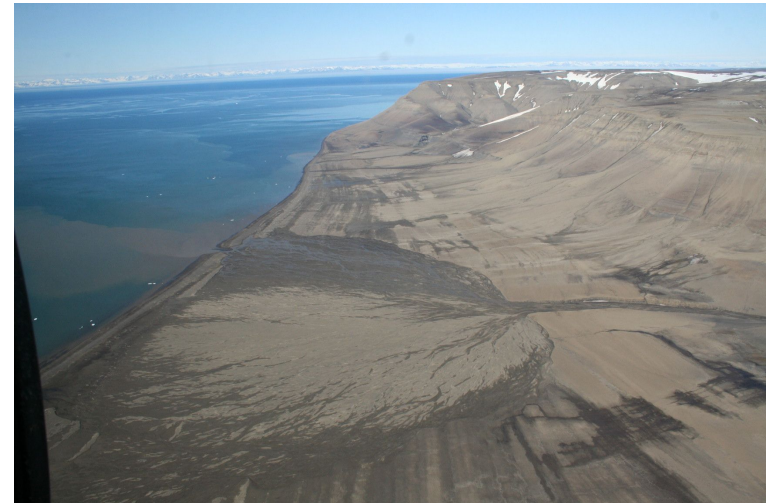


Map legend descriptions

5 - Wet, non-vegetated to sparsely vegetated flats, beaches, slopes and river fans (8,16,30). The unit integrate different types of non- to sparsely vegetated areas on moist to wet subsoil. The classes constituting this unit are represented both in lowland and in the mountains. Sterile, loamy flats, river fan mosaics, seashores and recent moraines bounding the glaciers are the main landscape elements within the unit



6 - Dry, non-vegetated to sparsely vegetated barrens, slopes and ridges (28,29,31). The general definition of the class is dry, non-vegetated areas both in lowland and in the mountains. The main occurrence of the unit is in the mountains associated to gravel barrens, exposed rocks, block fields and talus slopes. To some extent the most exposed parts of the Arctic Polar Desert Zone are included in the unit.

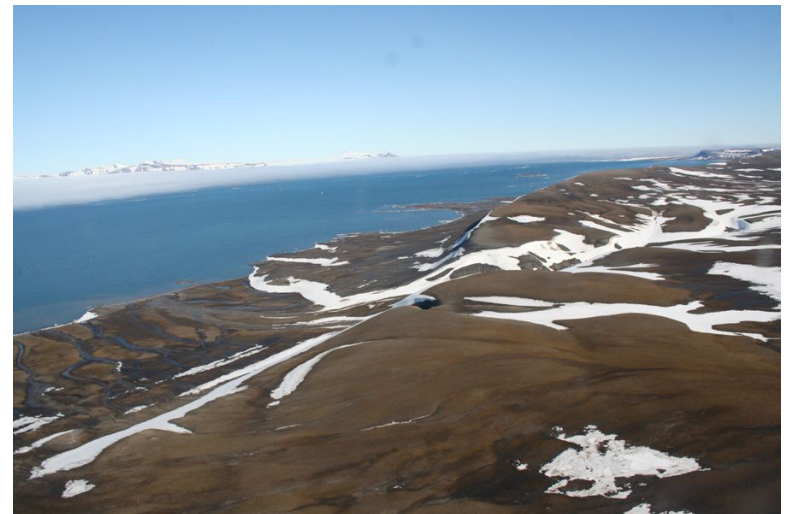


Map legend descriptions

7 - **Shade effects (5,7,9).**

- 8 - **Pioneer-vegetation (14,15,33).** In general pioneer vegetation comprises vegetation communities strongly affected by erosion and accumulation, both during times of flooding and as silt transport during the melting season. The map unit includes perennial mud flats, irrigating hill slopes, partly established river fans and salt marsh vegetation. In mountain areas instable snowbed communities constitute the class, characterized by few vascular species and mosses.

- 9 - **Moderate snowbed and snowflush communities (11,34,35).** Located to areas with snow protection during winter. The snow protects against the extensive arctic cold and desiccation. It further serves as a moisture source in early summer, and as a determinant for the duration of the growing season. Constitute large areas along the coast, mainly in the northern and eastern parts. On Reinsdyrflya community types of *Poa alpina* are developed.



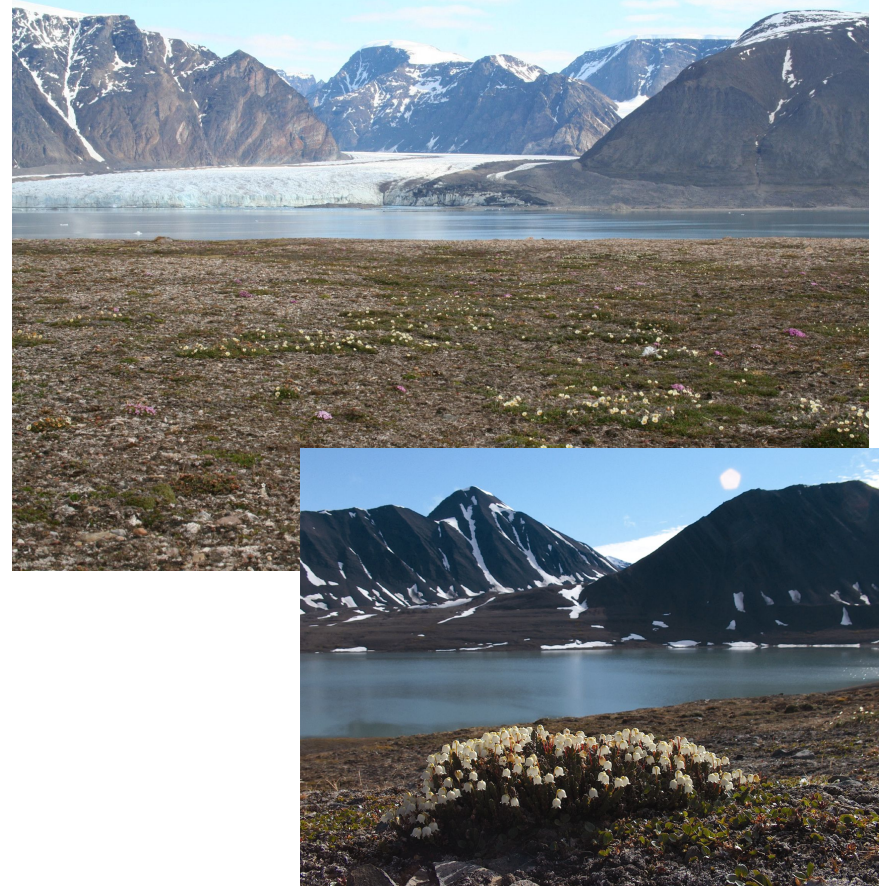
Map legend descriptions

- 10 - Swamp and wet moss tundra (10,36).** In general swamps are located to areas with stagnate, standing water, while wet moss tundra communities are located to gently sloping terrain, but still with the ground water just below the ground surface. Mosses characterize both community types. Swamp communities are often characterized by single species (*Arctophila fulva*, *Dupontia psilosantha*). The distribution is mainly restricted to the lowland.
- 11 - Hygrophilous marsh vegetation (13).** Hygrohilous marshes are most often developed in sloping terrain constituting grass-, sedge- and herb-rich communities. The water status varies from moist stands of mosses, grass and sedges to drier, shallow marshes with a more scantily developed moss layer. Characterizing species are *Dupontia fisherij*, *Eriophorum scheuchzeri*, *Carex paralella*, *C. saxatilis*, and *C. amblioryncha*. The communities types constituting this map unit are highly productive and of high importance as pastures for reindeer and geese.



Map legend descriptions

- 12 – Moist heather tundra (12).** Established, moist tundra communities located to areas with moderate snow cover during winter. Most often developed on moraine subsoil; on terraces, flats, established river-fans and in gentle hill slopes. The overall formation is a mixture of heather and moderate snowbed species. The moss layer is generally sparsely developed.
- 13 - Exposed Dryas tundra (22,37).** Community types developed on dry, exposed gravel ridges, terraces, beach ridges and river fans. The vegetation cover is discontinuous with sparse snow protection during winter. *Carex rupestris*, *C. nardina* and to some extent *C. misandra* are the characterizing species, combined with scattered *Dryas* and *Saxifraga oppositifolia*. In some areas lichens are of rather great importance.
- 14 - Established Dryas tundra (17,18,21).** Located to terraces, hill slopes and small depressions in the terrain. The most common variant is poor in species, while others may contain herb, sedge and lichens. In depressions and where less drained sites dominate, community types characterized by mosses in combination with *Cassiope tetragona*, are developed. On coastal plains *Saxifraga oppositifolia* communities, partly with lichens, may constitute large areas. In the mountains, as well as in most northern and easternmost regions community types of *Papaver* and *Dryas* are common.



Map legend description

- 15 - Arctic meadows (19,20).** Luxuriant vegetation communities characterized by grass and forbs, combined with a high species number. Located to flats and warm south- and southwest facing slopes with some supply of water during the growing season. The community types are mainly located to the MATZ zone constituting largest areas on Dickson Land, in Reindalen, Sassendalen and Colesdalen. To some extent luxuriant bird cliff vegetation, established densely vegetated river fans and communities of *Luzula confusa* are included in this map unit due to high reflectance in the NIR part of the spectrum.
- 16 - Open dry-grass communities (25).** The map unit comprises open, extremely dry communities characterized by grass, sedge and rush species. Often located to upper parts of steep hillsides, to ridges and shoulders on mountain plateaus. Common in the mos continental parts of the archipelago, developed as a specific high-arctic steppe vegetation characterized *Potentilla pulchella*, *Poa abbreviate* and *Puccinellia angustata*..



Map legend descriptions

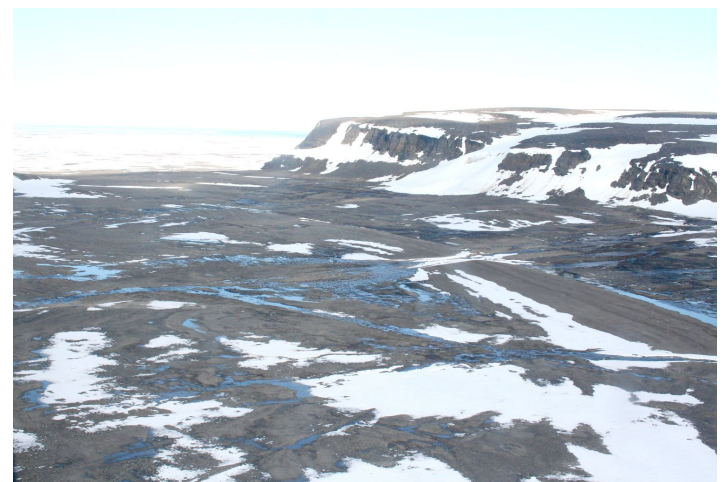
17 - Gravel barren communities (23,24)

constitute non- to sparsely vegetated gravel-, boulders- and block-fields, often characterized by large polygons. Species like *Papaver dahlianum*, *Saxifraga oppositifolia*, *Luzula arctica* and *Luzula confusa* are most common among vascular plants, while lichens may be abundant in areas with a stronger substrate stability. Gravel barren communities are often denoted polar deserts and mainly located to the mountain regions and to the northern and eastern islands of Svalbard (Nordaustlandet, Barentsøya and Edgeøya).

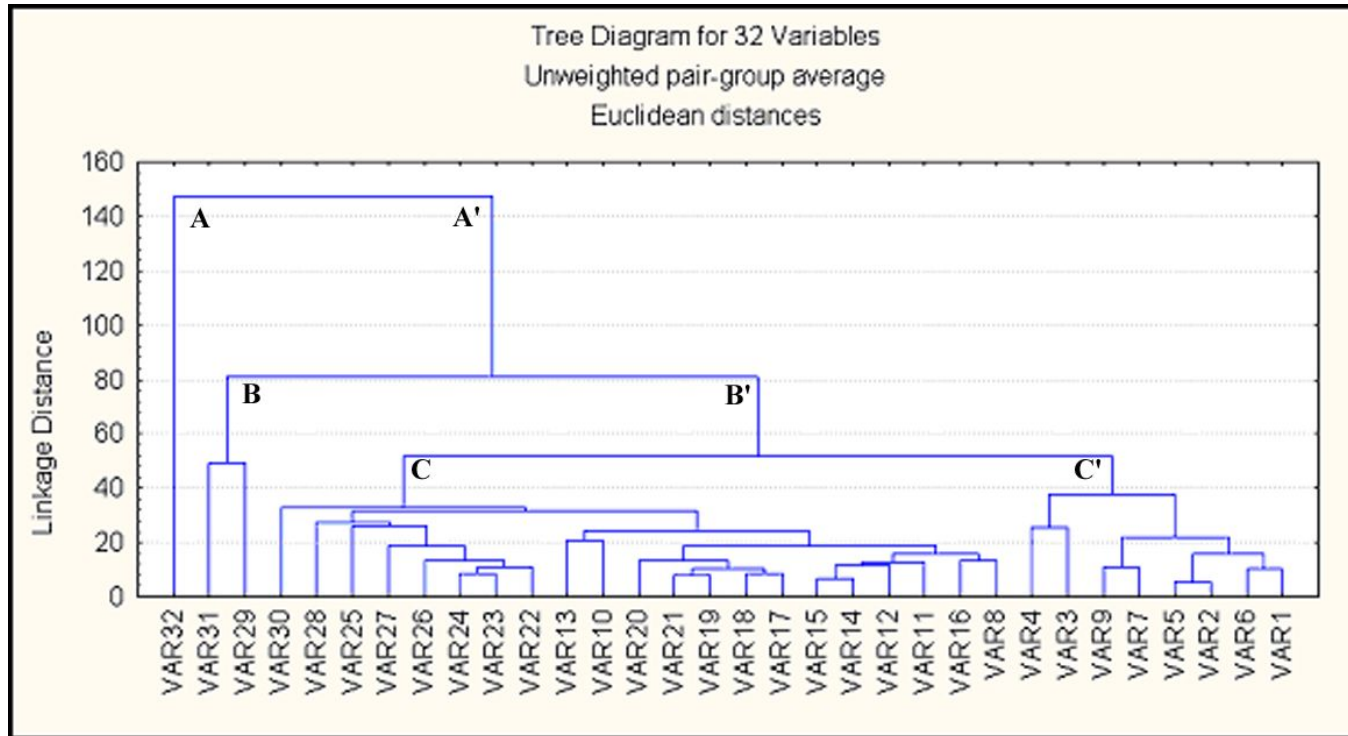


18 - Gravel snowbeds (26,27)

represent late snowbed and snow flush communities in the Arctic polar desert zone. The vegetation cover is open with scattered plants with *Cerastium regellii* and *Phippsia algida* as most common. The bryophyte layer may be densely developed, characterized by *Tomentypnum*, *Timmia*, *Pohlia* and *Distichium* species and liverworts. The main distribution on Svalbard is in the mountains and on the eastern islands.



Spectral interpretation of classes



- Glaciers
- Dry, non vegetated
- Wet, non vegetated
- Sparsely vegetated community types
- Exposed Dryas ridges
- Swamps, moss tundra hygrophilous marshes
- Arctic meadows, and established heather tundra (dense vegetation cover)
- Pioneer vegetation
- Open moist tundra
- Snowbed, snowflush areas
- Sparsely vegetated flats, seashores, river fans
- Rivers, meltwater
- Shade areas
- Open water, ponds, rivers, meltwater

Spectral reflection – map units

Nr	Org.	TM1	TM2	TM3	TM4	TM5	TM7	NDVI	Map units
1	1	40,95	30,19	27,63	26,08	17,59	14,77	-0,03	Sea, ocean
2	2	35,31	22,43	17,06	14,85	10,21	9,46	-0,07	Inland water
3	3	53,73	37,83	34,38	29,69	12,9	11,61	-0,07	Broad flooding rivers
4	4,6,32	115,11	100,46	109,92	97,22	15,02	13,31	-0,06	Glaciers, snow
5	8,16,30	43,73	34,25	35,37	39,23	40,64	34,23	0,05	Non-vegetated wet(beaches, flats, river fans)
6	28,29,31	54,79	48,37	55,04	64,55	79,26	66,16	0,08	Non-vegetated dry (barrens, slopes, ridges)
7	5,7,9	37	25,79	23,66	25,32	22,29	18,64	0,03	Shade areas
8	14,15,33	35,62	25,69	24,7	37,32	44,43	31,46	0,2	Pioneer vegetation, sparsely vegetated
9	11,34,35	34,16	24,27	22,65	39,76	35,99	23,73	0,27	Snowbed and snowflush areas
10	10,36	32,59	23,28	21,09	50,7	31,67	18,79	0,41	Swamp and moss tundra communities
11	13	33,01	24,83	23,09	59,5	47,87	27,25	0,44	Hygrophilous marsh communities
12	12	33,39	24,3	22,84	47,31	47,29	29,09	0,35	Moist heather tundra
13	17,22	39	29,59	29,99	44,52	54,9	39,86	0,2	Exposed heather tundra
14	18,21,37	35,98	26,19	25,57	41,13	56,96	38,57	0,23	Dryas tundra communities
15	19,2	34,12	25,15	24,12	50,27	57,41	34,74	0,35	Arctic meadow communities
16	25	35,43	27,4	27,08	61,22	68,49	41,3	0,39	Exposed dry grass communities
17	23,24	42,25	33,42	34,97	41,15	53,37	44,7	0,08	Gravel barren communities
18	26,27	45,88	38,15	41,4	48,65	61,47	51,27	0,08	Gravel snowbed communities

Table xx. Spectral reflection in all TM-channels and NDVI for each of the defined map units.

Map verification – Brøgger Peninsula (1)

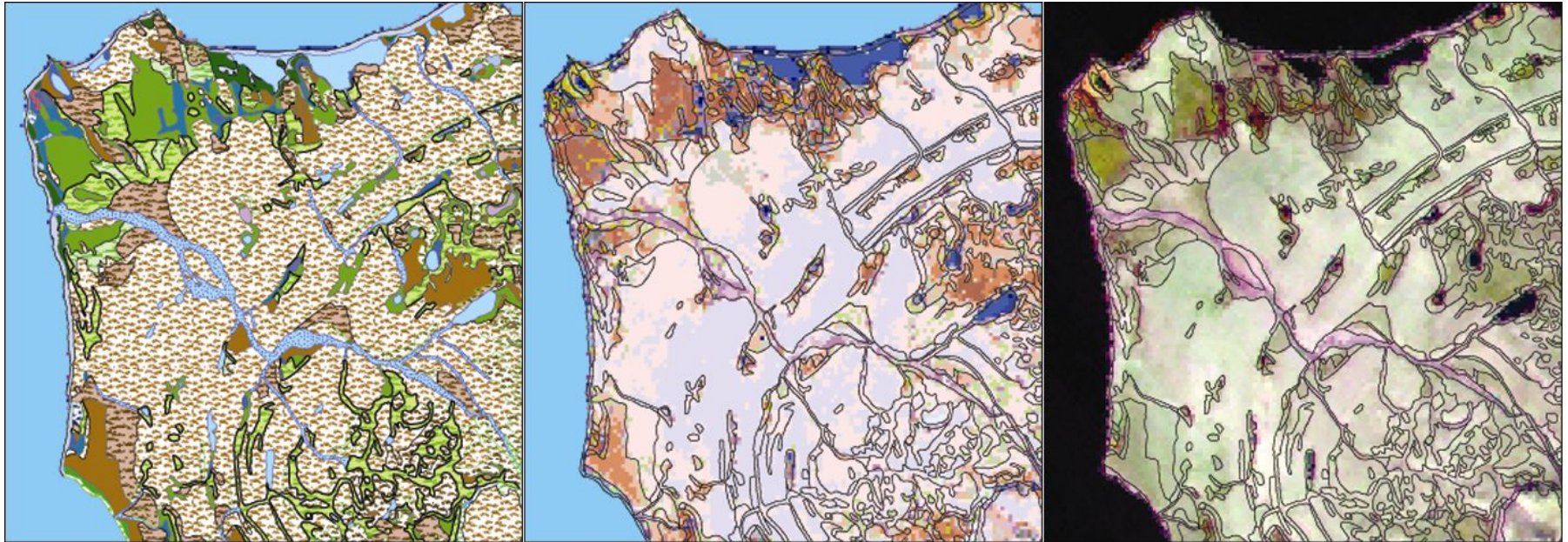


Figure: Map subsections from the northernmost parts of Brøgger peninsula. The conventional map is displayed to the left, the satellite based map in the middle and a 3-band Landsat image, ch 453, acquired the 16th of August 1998

Map verification – Gipsdalen (2)

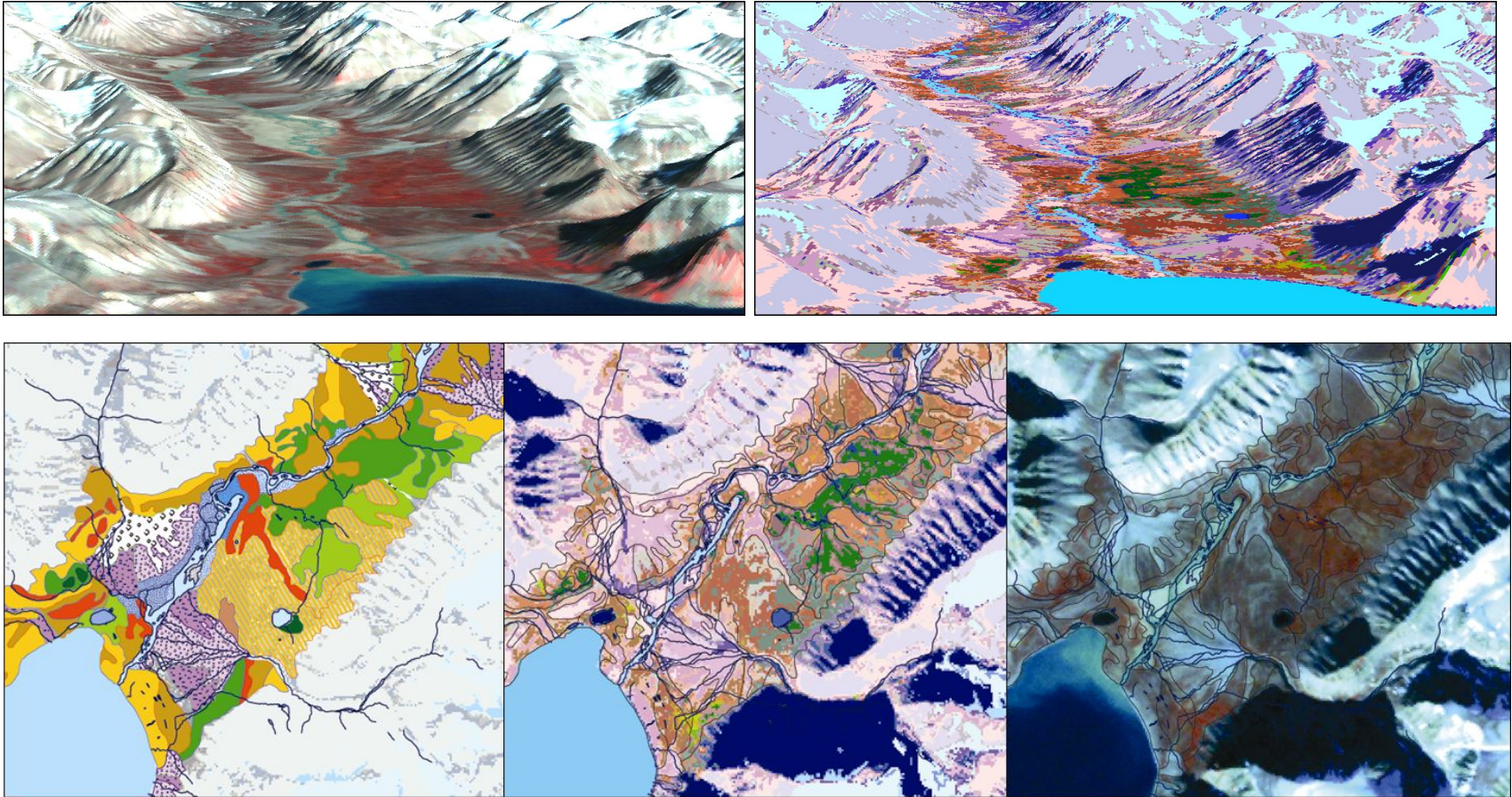


Figure xx. Map subsections from the Gipsdalen valley. A) Conventional map. B) Satellite based map. C) 3-band Landsat image, ch421.

Map verification - Edgeøya

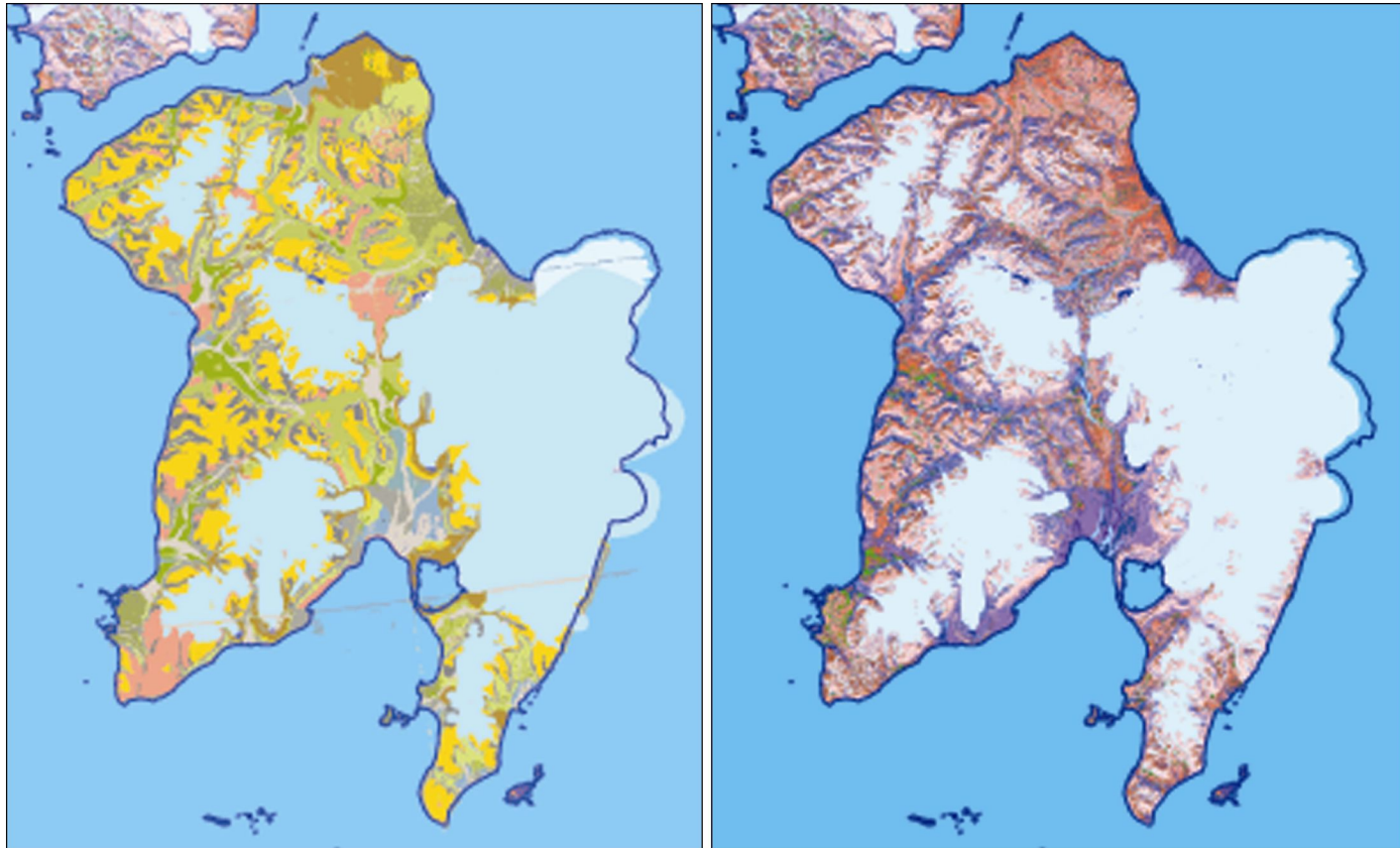
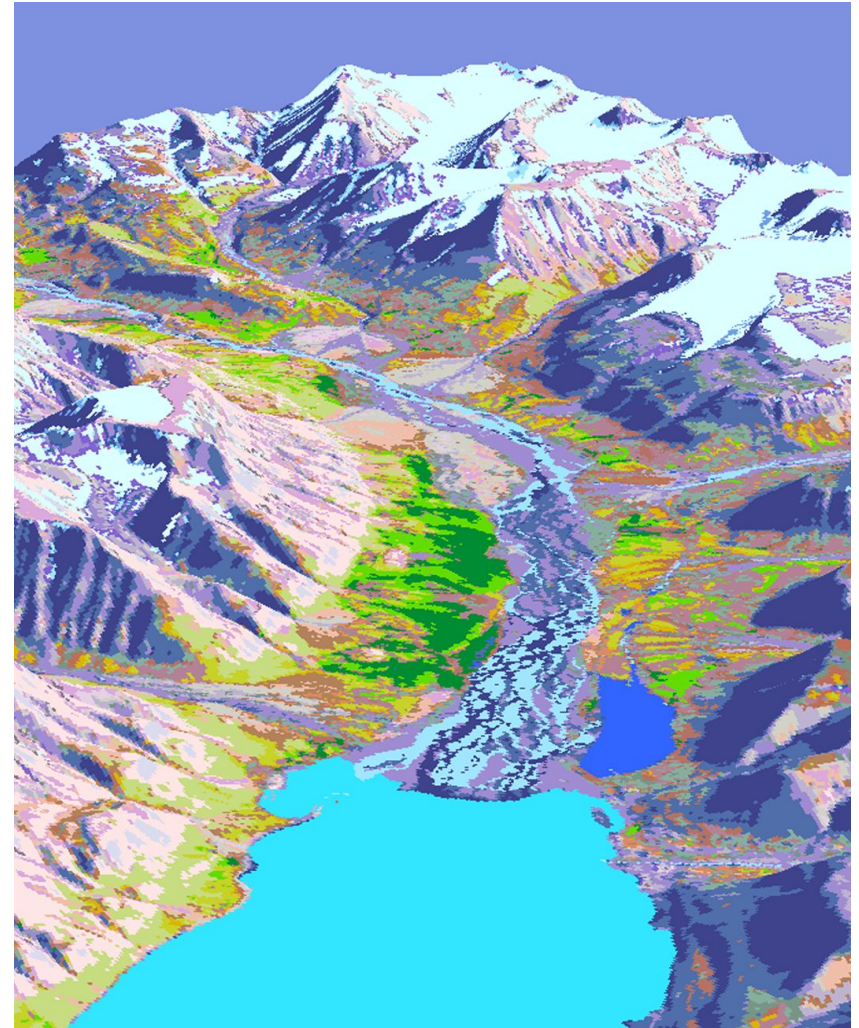


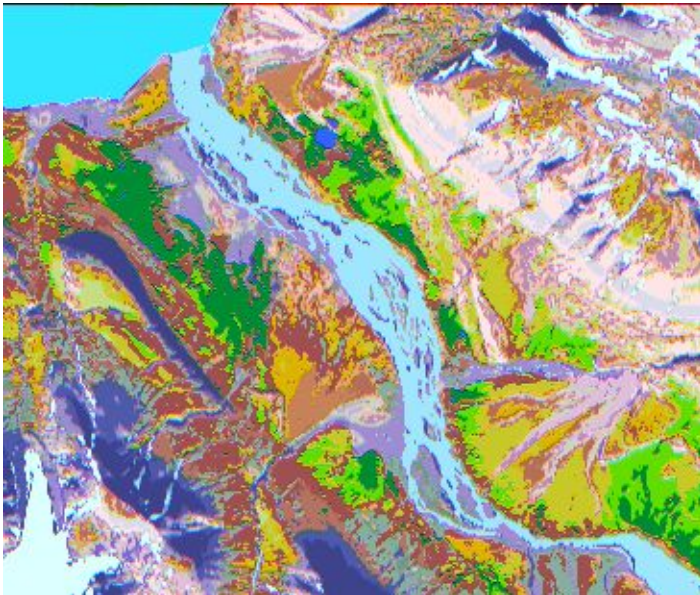
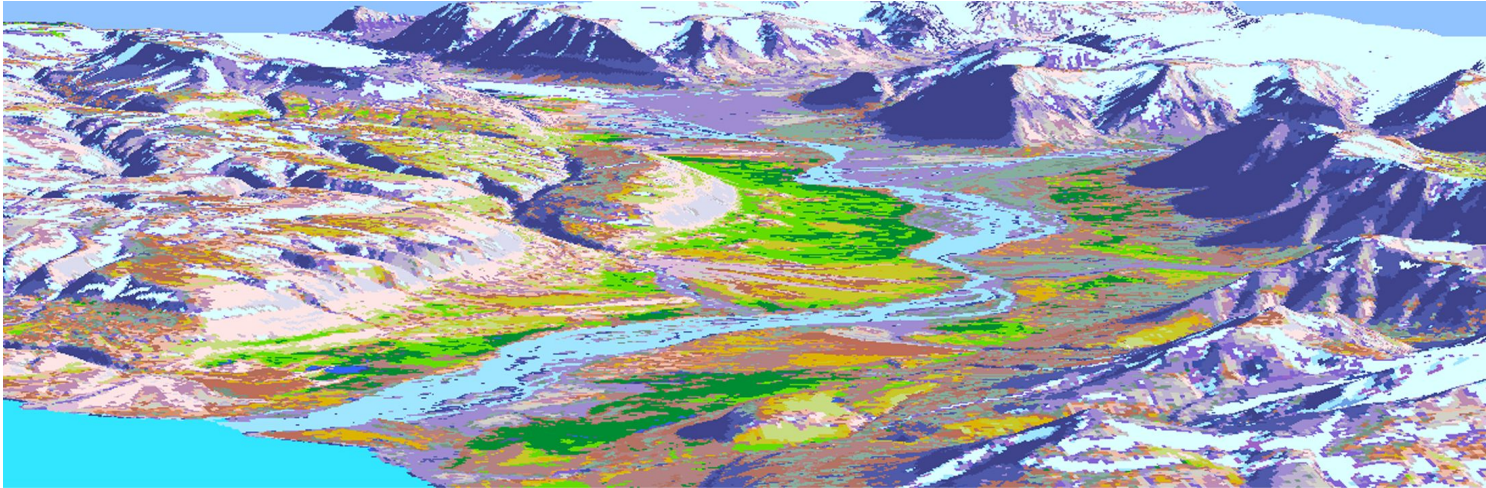
Figure xx. Edgeøya – landscape ecology map, original scale 1:200 000. (Zonnenwald 2005).

Map subsections



Adventdalen, Spitsbergen

Map subsections

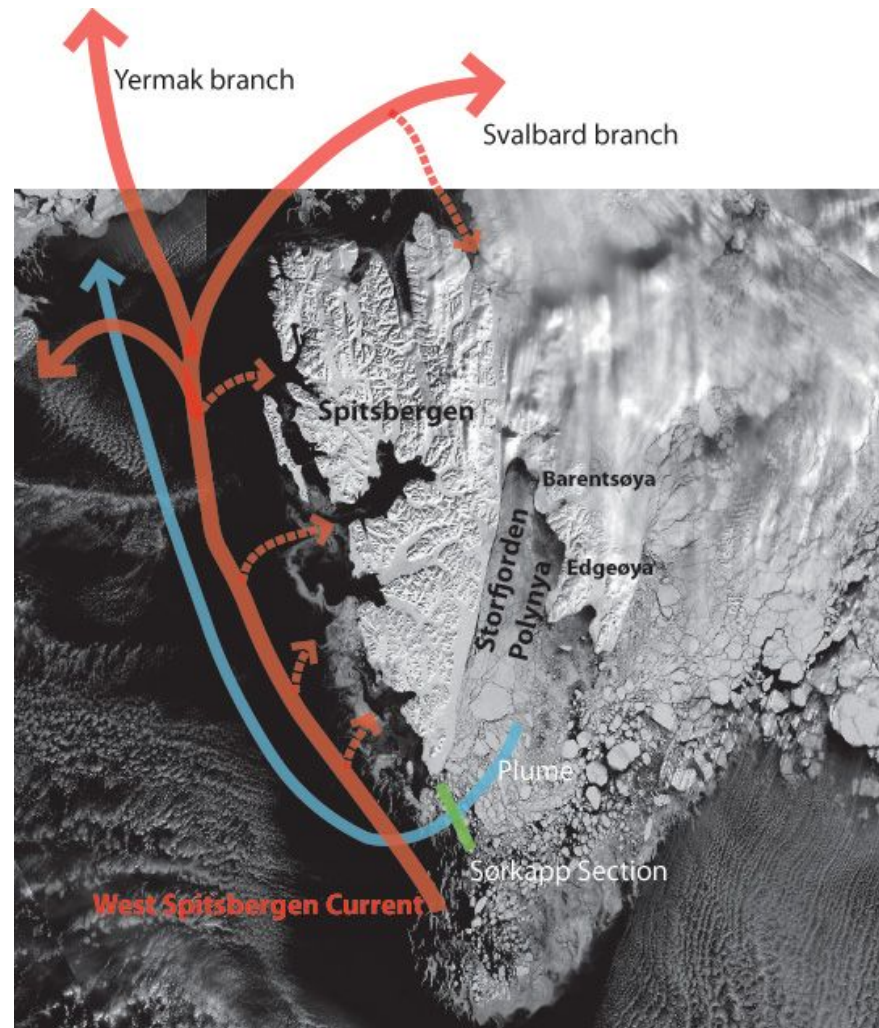


Sassendalen, Spitsbergen

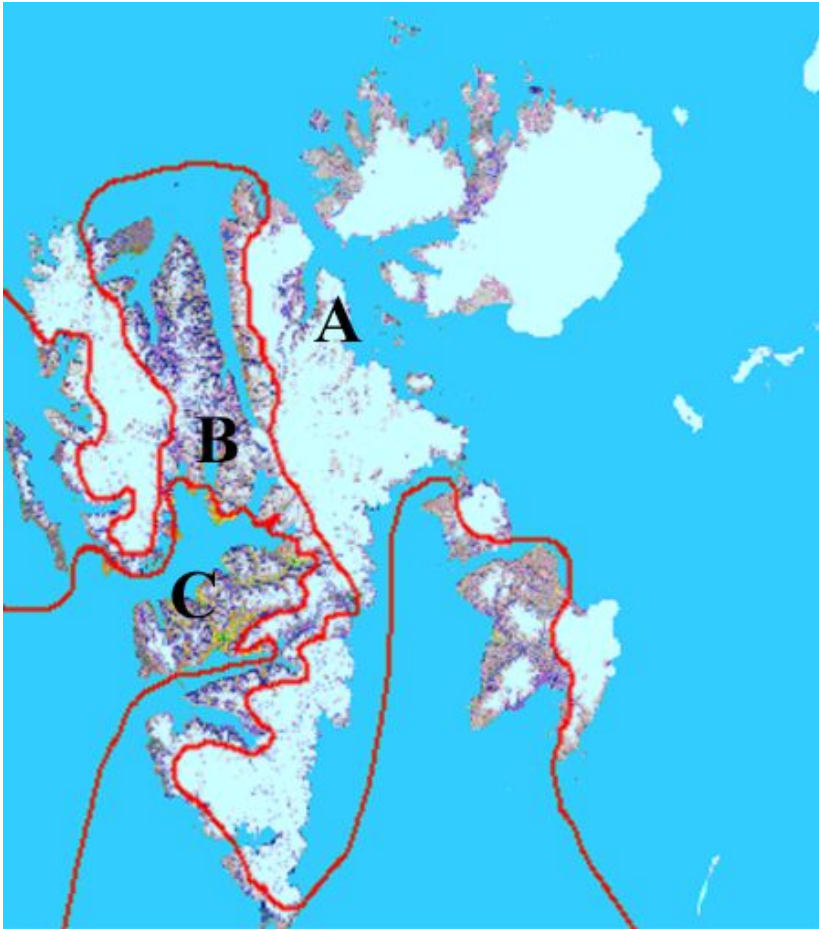
Svalbard – areal statistics

	Nordaut- landet	Spits- bergen NE	Spits- bergen N	Spits- bergen NW	Edgeøya/ Barents- øya	Spits- bergen Central	Spits- bergen S	Total	Map units
2	0,97	0,38	0,89	0,60	0,32	0,57	0,43	0,63	Inland water
3	0,04	0,35	0,55	0,64	1,23	1,48	2,01	0,78	Flooding rivers
4	76,46	82,04	34,91	68,41	44,22	18,49	69,57	61,65	Glaciers
5	4,30	5,01	14,12	6,42	11,80	14,20	8,88	8,23	Non-vegetated areas, wet
6	2,90	4,08	7,43	6,29	10,96	10,25	5,88	6,05	Non-vegetated areas, dry
7	0,92	2,50	16,85	7,04	6,03	15,05	7,81	6,71	Shadow effects
8	1,02	0,51	3,07	1,88	3,09	5,74	1,10	1,96	Pioneer-vegetation
9	0,43	0,11	2,23	0,37	0,00	1,71	0,12	0,61	Moderate snowbeds/snowflush
10	0,00	0,01	0,34	0,08	0,37	0,77	0,26	0,20	Swamp and wet moss tundra
11	0,00	0,02	0,02	0,00	0,77	1,52	0,19	0,25	Hygrophilous marshes
12	0,00	0,00	0,06	0,11	0,00	3,37	0,12	0,34	Moist heather tundra
13	0,00	0,13	0,93	0,49	5,50	2,60	0,48	1,09	Open sedge tundra
14	0,92	0,54	5,19	2,92	5,04	7,57	0,92	2,67	Established Dryas tundra
15	0,00	0,04	0,86	0,56	0,00	5,08	0,09	0,65	Arctic meadows
16	0,46	0,13	0,42	0,18	0,10	2,65	0,12	0,48	Open dry-grass communities
17	3,72	0,82	3,00	1,16	0,00	3,88	0,49	1,97	Gravel ridge communities
18	7,87	3,33	9,12	2,85	10,56	5,07	1,53	5,72	Gravel snowbeds
	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	

Svalbard – temperature conditions overall frame



Vegetation zones on Svalbard



- A – Arctic Polar Desert Zone (APDZ)
- B – Northern Arctic Tundra Zone (NATZ)
- C – Middle Arctic Tundra Zone (MATZ)

Conclusions

- Remote Sensing data is highly relevant for vegetation mapping of large areas like the archipelago of Svalbard
- Based on satellite data we can perform mapping at different levels: 1) – overall scales reflecting zones and sections. 2) – intermediate levels reflecting landscape features and 3) local scales reflecting the community type level
- Based on created maps and comparing with old maps vegetation monitoring can be performed within selected areas (Brøgger Peninsula)
- Use of satellite data are well suited for co-operation within different research areas

Improvements – further works

- Use of SAR/radar data in order to work out more precise delimitations of wetlands, moss tundra communities and snowbeds
- Time-series in order to evaluate the the onset, the “greening” and the end of the growing season
- Use of SAR/radar data to evaluate the snow melt in the spring/early summer period

Snow melt 2009

